AD-A040 755 APPLIED PSYCHOLOGICAL SERVICES INC WAYNE PA F/G 5/10
DEVELOPMENT AND VALIDATION OF AN EQUATION FOR PREDICTING THE CO--ETC(U)
FEB 77 A R WILLIAMS, A I SIEGEL, J R BURKETT F41609-75-C-0025
UNCLASSIFIED AFHRL-TR-77-8 NL

| OF |
AD
A040755

END
DATE
FILMED
7-77

AFHRL-TR-77-8

AIR FORCE

HUMAN RESOURCES

LABORATORY

AD A040755

AD No.
DDC FILE COPY

(12)

DEVELOPMENT AND VALIDATION OF AN EQUATION FOR PREDICTING THE COMPREHENSIBILITY OF TEXTUAL MATERIAL

By

Allan R. Williams
Arthur I. Siegel
Applied Psychological Services, Inc.
Wayne, Pennsylvania 19087

James R. Burkett
Steven D. Groff

TECHNICAL TRAINING DIVISION
Lowry Air Force Base, Colorado 80230

February 1977
Final Report for Period March 1974 – December 1976

AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235

NOTICE

When US Government drawings, specifications, or other data are used for any purpose other than a definitely related Government procurement operation, the Government thereby incurs no responsibility nor any obligation whatsoever, and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise, as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

This final report was submitted by Applied Psychological Services, Incorporated, 404 E. Lancaster Avenue, Wayne, Pennsylvania 19087, under contract F41609-75-C-0025, project 2313, with Technical Training Division, Air Force Human Resources Laboratory (AFSC), Lowry Air Force Base, Colorado 80230. Dr. James R. Burkett, Instructional Technology Branch, was the contract monitor.

This report has been reviewed and cleared for open publication and/or public release by the appropriate Office of Information (OI) in accordance with AFR 190-17 and DoDD 5230.9. There is no objection to unlimited distribution of this report to the public at large, or by DDC to the National Technical Information Service (NTIS).

This technical report has been reviewed and is approved for publication.

MARTY R. ROCKWAY, Technical Director
Technical Training Division

DAN D. FULGHAM, Colonel, USAF
Commander

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: AFHRL-TR-77-8
2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): DEVELOPMENT AND VALIDATION OF AN EQUATION FOR PREDICTING THE COMPREHENSIBILITY OF TEXTUAL MATERIAL
5. TYPE OF REPORT & PERIOD COVERED: Final rept. March 1974 – December 1976
6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Allan R. Williams, Arthur I. Siegel, James R. Burkett, Steven D. Groff
8. CONTRACT OR GRANT NUMBER(s): F41609-75-C-0025
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Applied Psychological Services, Inc., 404 E. Lancaster Avenue, Wayne, Pennsylvania 19087
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 61102F, 2313T402
11. CONTROLLING OFFICE NAME AND ADDRESS: HQ Air Force Human Resources Laboratory (AFSC), Brooks Air Force Base, Texas 78235
12. REPORT DATE: February 1977
13. NUMBER OF PAGES: 56
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): Technical Training Division, Air Force Human Resources Laboratory, Lowry Air Force Base, Colorado 80230
15. SECURITY CLASS. (of this report): Unclassified
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)
18. SUPPLEMENTARY NOTES
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

cognitive process
comprehensibility
information processing
intellective processes
psycholinguistics
readability
text analysis

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Norms for Air Force technical training materials were developed for seven previously developed Structure-of-Intellect and seven psycholinguistically oriented variables which have been used to assess the readability/comprehensibility of textual materials. Separate norms are presented for Air Force study guides, manuals, career development course materials, and technical orders. An "overall" norm is also presented along with norms on the same variables for a small sample of general literature. A multiple linear regression equation, which relates the various comprehensibility measures to measured comprehensibility, was developed and cross-validated.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

031 800

PREFACE

We acknowledge the contributions of a number of individuals toward the completion of the work described. At Applied Psychological Services, Inc., text analysis for preparation of norms was performed by Debra Edelstein, Leslie Gossage, Susan Jacobs, Jane McCarty, Aron Wolf, and Pamela Wilson.

Subject groups were willingly provided by Mr. J. Carabba of the Central Chester County Vocational Technical School, Mr. J. Keaveney of the Norristown Office of the Pennsylvania Bureau of Employment Security, Mrs. P. Jackson of the Opportunities Industrialization Center, Philadelphia, Pa.; Dr. Mark Pfeiffer of LaSalle College, and Dr. J. Smith of the Pennsylvania State University, Ogontz campus.

At the Air Force Human Resources Laboratory, Dr. Roger Pennel, Dr. Philip DeLeo, and Major Brian K. Waters provided assistance on statistical analyses.

We express our indebtedness to all of these persons.

TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

LIST OF FIGURES

LIST OF FIGURES (cont.)

LIST OF TABLES

LIST OF TABLES (cont.)

I. INTRODUCTION

Background

For a number of years, the Air Force Human Resources Laboratory has sponsored research into methods for measuring and improving the comprehensibility of textual materials used during Air Force technical training. The long range goal of this research has been to develop methods for reliably measuring and increasing the comprehensibility of textual materials and thereby allow a reduction in training time and costs, as well as an increase in training effectiveness.

A number of efforts toward this goal have been completed to date. Williams, Siegel, and Burkett (1974) reviewed the methods for predicting comprehensibility of text which were developed through the year 1972. They pointed out that research activity into language behavior relevant to reading comprehension was growing, and that no theories or hypotheses useful in the prediction of textual comprehensibility were available until very recent years.

Siegel and Bergman (1974) developed and tested a set of variables related to readability which were based on selected intellective activities as described in the Structure-of-Intellect model of Guilford (1966, 1967). Lambert and Siegel (1974) followed similar procedures in developing and testing a set of variables based on constructs described in the psycholinguistic literature. Siegel, Williams, Lapinsky, Warms, Wolf, Groff, and Burkett (1976) investigated these Structure-of-Intellect and psycholinguistic variables and presented a technique for measuring the variables by computer.

In addition, two other technical reports have been prepared. In one (Siegel, Federman, & Burkett, 1974), techniques are presented, in nontechnical language, for predicting text readability and for experimentally measuring text readability. The second report (Siegel, Lambert, & Burkett, 1974) presents a series of concepts the implementation of which would tend to improve the comprehensibility of technical writing.

The research in this report extends the prior studies related to Structure-of-Intellect and psycholinguistically oriented variables.

Readability Indices

Williams et al. (1974) described 48 readability formulas developed prior to 1973. Generally, the procedure followed in developing these formulas involved computing a multiple linear regression equation which related measurable characteristics of text to comprehensibility, defined as a comprehension test score [such as cloze test score (Taylor, 1953)] or judged difficulty.

The factors included in most, if not all, readability equations have involved measures taken within sentences only. No readability equation exists, to our knowledge, which considers factors distributed across sentences, such as ideational density, organization, obscurity of expression, etc. These, however, are the points which are emphasized in various guides for readable writing.

The factors which are considered in readability equations, in addition, have been chosen because they are easily measured. They did not stem from theories or hypotheses regarding language processing. Accordingly, it can be held that they lack construct validity. One would expect that readability measures based on theory or hypotheses concerning language processing would be more useful and possess greater diagnostic value than measures based on molecular characteristics of text which, if manipulated in isolation, have little effect on comprehensibility. For example, the writing of Gertrude Stein is very difficult to read, despite the short sentences and simple vocabulary which characterize her work. The two most popular readability formulas, Flesch "reading ease" and the Dale-Chall formula, rate samples of Stein's work as very easy reading (Taylor, 1953).

Also, the developers of prior readability predictive equations have frequently pointed out that their indices only measure readability. They tell the author little about how a given text may be modified to increase its readability. In fact, developers of these indices have warned against employing their formulas in reverse to increase readability.

This fact along with the inability of readability equations to accurately measure atypical text suggest that they do not address the factors or variables which are actually involved in human processing of written language. Rather, such factors only address correlates of the "true" factors. Bormuth (1969) argued that only sentence structure and syntactic complexity may determine comprehension difficulty. Modification of word length and sentence length may influence comprehension only to the degree that they affect the syntactical or phonemic structure of messages.

In order to extend the constructional scope of textual comprehensibility measurement and incorporate a diagnostic capability, the Air Force Human Resources Laboratory has sponsored research to define, quantify, and verify comprehensibility measures which are based on concepts drawn from both the psycholinguistic and the intellective structure literature.

Psycholinguistically Oriented Comprehensibility Measures

In an attempt to isolate textual comprehensibility measures based on or oriented towards language processing constructs, Lambert and Siegel (1974) surveyed the literature to isolate psycholinguistically oriented variables which might influence reading comprehension. They identified a number of such variables: Yngve depth, morpheme depth, transformational complexity, center embeddedness, left branching, right branching, and complement deletion.

As pointed out by Bormuth (1966), until very recent years no theoretical base was available from which to generate testable hypotheses relating to readability. Modern linguistic and psycholinguistic research activities have begun to fill this void. But due to the apparent effectiveness of the simple, structural variables and the complexity of the variables contained in new language theories, researchers still seemed to lean toward the structural variables (e.g., Coleman & Liau, 1975). Only research-oriented formulas, such as those of Bormuth (1969), seemed to have employed variables based on theory. However, the variables in Bormuth's formulas are difficult to measure and rely on sentence analysis by skilled persons.

The current effort to develop a readability equation for applied use was undertaken with the assumption that the variables could be measured by computer. We assume that programs can be written which will perform certain sophisticated language analyses which are too time consuming and difficult for routine manual performance, and Siegel et al. (1976) provides a detailed description of a computer program capable of measuring the variables described below.

Yngve Depth (YD)

Yngve (1960) developed a model of sentence production on the basis of conjecture that a person produces sentences by generating a "sentence structure tree" in a top-to-bottom, left-to-right direction. According to this model, at any given time a speaker has produced only that portion of the left-hand side of the tree necessary to produce the word spoken. As the speaker works down the tree, he produces both branches of a node, but he must store the right branch in memory while he is expanding the left branch. Yngve depth is, thus, a measure of the memory demand placed on the person reading or auding the sentence. Bormuth (1969) found that sentence depth was correlated with the difficulty of a passage. Martin and Roberts (1966) held sentence length constant and varied the Yngve depth. They found that sentences of lesser complexity were recalled significantly more frequently than sentences of greater structural complexity. The finding that mean linguistic depth is a strong predictor of sentence comprehensibility has been confirmed by Wang (1970), Lambert, and Siegel (1974), and Siegel et al. (1976).

Morpheme Depth (MD)

A morpheme is the meaning carrying unit of language, and does not always correspond to the syllable. For example, the word "flower" is one morpheme. Bormuth (1969) speculated that the comprehensibility of an individual word may depend on how many morphemes are "buried" within it. Consider the word

un/happi/ness

un = morpheme denoting "not"
happi = morpheme denoting a state of mood
ness = morpheme denoting a condition or quality

A person reading this word must have knowledge of the meaning of all three morphemes to comprehend the word.

Lambert and Siegel (1974) and Siegel et al. (1976) found the mean number of morphemes per word to be related to comprehensibility.

Transformational Complexity (TC)

According to theories of transformational grammar, sentences of any type or level of complexity are produced, or interpreted, through transformations relative to simple, active "kernels." Interpretation of passive, negative, or passive negative sentences or independent clauses requires successively more, or more elaborate, transformations from the basic active kernel. The TC of a sentence is a measure of the number of transformations from its kernel. Lambert and Siegel (1974) found the relative accuracy of interpretation of sentences of these four classes of transformations to decline in the order described above.

Center Embedding (CE)

If phrases or clauses appear between the subject and the predicate of a sentence, such phrases or clauses are said to be center embedded. Schwartz et al. (1970) demonstrated that inclusion of center embedded material decreased comprehensibility. The results of Lambert and Siegel (1974) supported the findings of Schwartz et al. However, Siegel et al. (1976) found that center embedded materials were associated with higher cloze scores. They suggested test method bias as a possible cause of the inconsistent findings across studies.

Left Branching (LB) and Right Branching (RB)

Schwartz et al. (1970) also found that addition of phrases or clauses to the left of the subject decreased comprehensibility. Addition of similar material following the sentence predicate did not degrade comprehensibility. Lambert and Siegel (1974) tested these variables and obtained mixed results. Siegel et al. (1976) found both the left branching and the right branching variables to affect cloze score, although the effect of right branching was not in the anticipated direction.

Complement Deletion (DC)

It has been hypothesized that certain surface structures of language, such as the complement "that" in "He said that I should go," may serve to mark the deep structure of a sentence, and so contribute to its comprehensibility. Hakes (1972) demonstrated this effect. Lambert and Siegel's (1974) results disagreed with Hakes' and found a significant effect in the opposite direction. Siegel et al. (1976) corroborated the findings of Lambert and Siegel.

Intellective Theory Oriented Comprehensibility Measures

Guilford and his associates (1950, 1954, 1964, 1966, 1967) developed a three-factor taxonomy of human mental activity. Based on factor analytic procedures, 120 nonoverlapping intellective activities have been described. The three factors isolated by Guilford include: (1) "contents," indicative of the form in which information may be presented, (2) "operations," describing the types of processing applied to the information, and (3) "products," which describe the forms in which the output of the operation may occur. Within contents, four categories exist: figural, symbolic, semantic, and behavioral. Five operations are identified (cognition, memory, convergent production, divergent production, and evaluation) as well as six categories of output (units, classes, relations, systems, transformations, and implications). Each combination of one content, one operation, and one product represents one unique class of intellective function. . The classes, based as they are on combinations of categories within three orthogonal factors, may be represented as a cube composed of 120 cells. A representation of the Guilford Structure-of-Intellect (SI) model is presented as Figure 1. Guilford and his colleagues have identified examples of performance and tests for the majority of the 120 cells.

Siegel and Bergman (1974) hypothesized that textual materials which require a high level of SI ability would be less comprehensible than would texts requiring the same SI ability at a lower level. This work examined various Guilford categories and selected eight which seemed most relevant to the readability/comprehensibility problem in the Air Force technical training context.

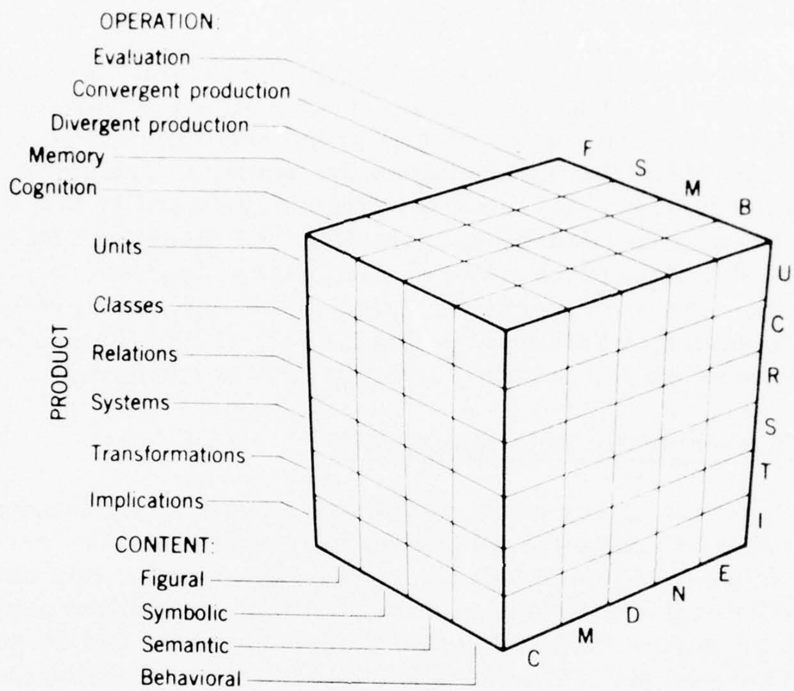

Figure 1. Guilford's Structure-of-Intellect model.
(Guilford & Hoepfner, 1971)

Siegel and Bergman postulated these Guilford abilities to represent an intervening variable between the surface structure of a text (the structure as the message is presented on a page) and the deep structure (the structure of the message after transformation to simplest form is completed). This intervening variable, called intellective load, has to do with the intellective processes (type and amount) required for converting the coded language into a meaningful message.

Cognition of Semantic Units (CMU)

Guilford (1967) defined cognition of semantic units as a vocabulary factor, stating it is most directly measured by vocabulary tests. Here, CMU in the context of prose reading is held to involve the extent to which the text requires the reader to recognize a diversity of word forms. Measures of vocabulary diversity are commonly found in existing readability formulas, and Siegel and Bergman (1974) found a significant effect of vocabulary diversity on comprehensibility. The CMU variable, equal to the type-token ratio subtracted from one, was found by Siegel et al. (1976) to significantly affect cloze score for both low and high ability readers.

Cognition of Semantic Relations (CMR)

Cognition of semantic relations was defined by Guilford (1967) as the ability to recognize a relationship between items or words and analogy and word linkage tests were used to measure this ability. Siegel and Bergman (1974) demonstrated that incomplete analogies and unclear word linkages degrade comprehension, and Siegel et al. (1976) developed a CMR comprehensibility measure which attempted to assess unclear linkages through the number of shared nouns (nouns appearing in adjacent sentences) and number of pronouns. Siegel et al. (1976) verified that such a measure significantly influenced cloze score for high- and low-ability readers.

Memory for Semantic Units (MMU)

According to Guilford (1967), memory for ideas is most directly addressed by memory for semantic units. Siegel and Bergman (1974) demonstrated that replication of facts increased comprehensibility. Assuming that the new ideas will be presented using new nouns, an analogous measure seemed to be the number of different nouns appearing in a passage divided by the number of words in the passage; this measure seemed to serve as an index of memory burden. Siegel et al. found that this MMU measure affected comprehension in the hypothesized direction.

Evaluation of Symbolic Implications (ESI)

Guilford (1967) used abbreviations tests to measure evaluation of symbolic units. A corresponding readability measure was thought to involve the frequency of occurrence of abbreviations in passages of running text. Siegel and Bergman (1974) and Siegel et al. (1976) demonstrated that frequency of occurrence of abbreviations influenced comprehension.

Convergent Production of Semantic Implications (NMI)

Guilford and Hoepfner (1971) used syllogisms, attribute listing, missing links, and sequential association tests to measure convergent production of semantic implications. Reading material loaded in convergent production requires the reader to perform syllogistic reasoning tasks, and material which does not require this ability would complete the syllogism for the reader. Increase of the convergent production of semantic implications load in a text should decrease comprehensibility. Siegel and Bergman (1974) found that textual material which imposed syllogistic reasoning demands on the reader was less comprehensible than that not demanding such reasoning.

Identification of the number of syllogisms in a text is quite difficult. Accordingly, a measure was developed in which the number of words of a passage is divided by the total of the dictionary-listed numbers of parts of speech of the words of the textual sample. This was considered to be an index of the number of possible parses of a sentence and thus analogous to a measure of syllogistic reasoning. Siegel et al. (1976) found this measure to be related to comprehensibility, although not in the predicted direction.

Divergent Production of Semantic Units (DMU)

According to Guilford (1967), divergent production of semantic units involves the ability to enumerate class members given certain class properties. With regard to the readability of training texts, divergent production of semantic units would require the reader to enumerate class members on his own rather than have the class member supplied by the reading selection. Siegel and Bergman (1974) demonstrated a relationship between the presentation of examples and comprehension, and the results of Siegel et al. (1976) confirmed these findings.

Convergent Production of Semantic Systems (NMS)

Guilford (1967) relates convergent production of semantic systems to skill in ordering. Siegel and Bergman (1974) demonstrated that passages containing mnemonic devices and similar memory aids were more readily comprehended by readers than were similar passages lacking these aids. The NMS measure is defined as the number of such aids in a block of text arbitrarily divided by four.

Objectives of Present Work

As described above, a series of studies into the potential usefulness of psycholinguistic and intellective oriented variables for measuring and increasing the comprehensibility of textual materials has already been completed. These studies established methods for measuring these variables and evaluated the measures. Additionally, these studies provided a function specification for a computer program for calculating these measures.

The goals of the present work were to extend the prior work and to:

1. develop norms of occurrence of the psycholinguistically and the SI oriented comprehensibility variables previously developed and described;

2. further verify the measures and develop the best linear combination of the variables for predicting the comprehensibility of Air Force training materials.

II. DEVELOPMENT OF NORMS

The psycholinguistic and SI oriented comprehensibility measures which were included in prior studies (Chapter 1) and in the functional computer implementation description are presented and defined in Tables 1 and 2.

Normative data were desired describing the occurrence of the listed psycholinguistic and SI variables in four types of Air Force publications: (1) study guides employed in formal classroom training, (2) manuals and regulations of the type used for field and occasional classroom reference, (3) career development course (CDC) texts (self-study materials taken by enlisted personnel to meet a portion of the requirements for skill upgrading), and (4) technical manuals (publications presenting the specific methods and procedures to be followed on the job and related information). One hundred fifty nonsequential pages from each category of document were provided for this purpose by the Air Force Human Resources Laboratory. The range of subjects represented by the provided pages is indicated in Table 3.

From each of the Table 3 categories, 50 blocks of text were selected to yield normative data. In order to select each desired sample of 50 blocks, the number of column pages of running prose in each sampled category was determined. [In instances in which there were two columns of text on a single page, as in CDCs, each column was considered as a separate page.] The total of the column pages was then divided by 50. The number so obtained represented the interval between beginnings of the passage blocks selected. The starting point of a block was adjusted forward or backward, whichever allowed the least displacement, so that a major change of topic did not occur within the finally chosen block.

Each block began at the beginning of a sentence and ended at the first sentence end after the 99th successive word. Selected passages were, thus, approximately 100 words in length. Only sentences of running prose were included in the selected samples. Word counting was suspended when paragraph headings, lists presented in outline form, and the like were encountered. Samples were not strictly limited to a particular number of words since several measures were derived from characteristics of whole sentences (e.g., CMR, DMU, YD) or employed number of sentences as a base.

Table 1

Summary of Comprehensibility Measures

Formula	*Abbreviation*	*Name*
Structure-of-Intellect		
$1 - \frac{NDWB}{TNWB}$	CMU	Cognition of Semantic Units
$\left(\frac{NSNB}{TNSB - 1} + NORB\right) / TNWB$	CMR	Cognition of Semantic Relations
$1 - \frac{NDNB}{TNWB}$	MMU	Memory for Semantic Units
$1 - \frac{NSWB}{TNWB}$	ESI	Evaluation of Symbolic Implications
$\frac{TNWB}{TPSB}$	NMI	Convergent Production of Semantic Implications
$\frac{TNEB}{TNSB}$	DMU	Divergent Production of Semantic Units
$\frac{TNAB}{4}$	NMS	Convergent Production of Semantic Systems
Psycholinguistic		
$\frac{TNWB}{TNSB \cdot \sum_{W} YDS}$	YD	Yngve depth
$TNWB/TNMB$	MD	Morpheme depth
$\sum_{S} TCS/TNSB$	TC	Transformational complexity
$1 - \frac{\sum NNPS}{TNSB}$	CE	Center embedding
$1 - \frac{\sum_{S} NCLS}{TNSB}$	LB	Left branching
$TNSB/\left[\sum_{S} NCRS + TNSB\right]$	RB	Right branching
$1 - \left[\sum_{S} DCS/TNSB\right]$	DC	Deleted complements

Table 2

Symbology for Table 1 Formulae

NDWB	Number of different words in a text block
TNWB	Total number of words in a text block
NSNB	Number of shared nouns, count of nouns in adjacent sentences
NORB	Number of references (number of pronouns) in a text block
NDNB	Number of different nouns in a text block
NSWB	Number of abbreviated or symbolic words in a text block
NPPB	Number of potential parses per sentence
TNMB	Total number of morphemes per block
TNEB	Total number of elucidations per block
TNSB	Total number of sentences per block
NNPS	Number of noun phrases to the right of the subject verb in a sentence
NCRS	Number of modifying clauses on the right of the object noun phrase of a sentence
DCS	Deleted complement in a sentence
YDW	Sum of all digits on parse paths to each word of block
NCLS	Number of chained modifying clauses on the left of the subject noun of a sentence
YDS	Yngve depth of sentence
TCS	Transformational complexity value for a sentence
TPSB	Total number of parts of speech in all words of a block
TNAB	Total number of aids per block

Table 3

Sources of Passages Analyzed for Development of Norms

Category (1). Study Guides

Course No.	Air Force Specialty or Course Name
3ABR23132	Still Photographic Specialist
3ABR23330	Continuous Photographic Specialist
3AZR46350	Nuclear Weapons Specialist
3ABR32430	Precision Measuring Equipment Specialist
3AQR32020	Electronic Principles (Modular Self-Paced)
3ABR64530	Inventory Management Specialist

Category (2). Manuals and Regulations

Manual No.	Content
AFM67-1	USAF Supply Manual
AFM50-34	Military Training Standard, Promotion Fitness Examination, Study Guide
AFR127-101	Ground Accident Prevention Handbook
AFM50-23	On-the-Job Training
AFM52-1	Ground Cameras and Photo Lab Equipment
AFM52-2	Principles and Practices for Precision Photographic Processing Laboratories
AFM50-62	Principles and Techniques of Instruction
ATC52-___	Selections from ATC Regulations, 52- series

Category (3). Career Development Course Texts

Course No.	Air Force Specialty
CDC32450	Precision Measuring Equipment Specialist
CDC23152	Still Photographic Specialist
CDC23350	Continuous Photoprocessing Specialist
CDC46350	Nuclear Weapons Specialist
CDC64550	Inventory Management Specialist
CDC64750	Materiel Facilities Specialist

Category (4). Technical Manuals

Manual No.	Title
T.O.IF-4C-2-18	Maintenance Instructions, Armament Systems, USAF Series F-4C Aircraft
T.O.IF-111A-2-11-1	Organizational Maintenance, Armament Systems, USAF Series F-111A Aircraft
T.O.33D7-42-1-122	Service with Operation, FB-111A Shop System
T.O.IF-111D-2-4-1	Organizational Maintenance, Flight Control Systems, USAF F-111D Aircraft
T.O.31-1-141-3	Basic Electronics Technology and Testing Practices
T.O.33D7-24-8-2	Service with Operation, Video Test Station Type AN/ASM-433
T.O.12-1-63	Basic Theory and Application of Transistors
T.O.00-20-14	Air Force Metrology and Calibration Program
T.O.11N-W69.90-2	Ground Handling for AGM-69A Missile

Analysis of Text Samples

Analysis of the selected textual passages was performed by a team of persons who are highly familiar with grammatical and related language constructs. The analytic team members were upper-level college undergraduates and graduate students majoring in literature, foreign languages, and linguistics. They analyzed the selected text passages according to a strictly specified set of rules and descriptions of the various measures. These rules were contained in a specially prepared "analyst's manual." Prior to performing any analyses, the analysts were given three days of formal training and practice in deriving the various measures.

In order to determine whether the analysts were computing the SI and psycholinguistic variables with a reasonable degree of accuracy, the word counts involved in the calculations of six variables were selected for intensive study. Analyst data from two passages were inspected to determine consistency. On three of the variables (TC, DC, and ESU) there was absolutely no variation between analysts on either of the passages, though there was variance across passages. That is, each analyst arrived at the same score for each variable within a passage. On the remaining three variables (MD, MMU, and CMU) there was some variation both between analysts and between passages. These data were subjected to analysis of variance following the procedure given in Winer (1971, section 4.5). The reliability of six judges (analysts) is approximated by the expression $1 - MS_{within}/MS_{between}$, where MS_{within} refers to the variation averaged across judges and $MS_{between}$ is the variation between passages. Unbiased estimates of these reliabilities were .84, .91, and .98 respectively. Single judge reliabilities were lower--.40(MD), .63(MMU), and .95(CMU), respectively.

Rating of the remaining measures was performed by two or three members of the original group. Within the smaller group, a policy was initiated according to which all work was checked by at least one person other than the one who took the original measure. In this way, the manner of dealing with measures in which some variability was possible (e.g., Yngve depth, YD, and convergent production of semantic implications, NMI) was made consistent, and the accuracy of the final measures was controlled.

Results of Text Analysis

On completion of the analysis of a category of text material, for each measure, the 50 obtained values were ordered by magnitude, and the 9 deciles were identified. The first decile is equal to the mean of the fifth and sixth values from the bottom of the ordered list, the second decile is equal to the mean of the tenth and eleventh values, and so on. These values are presented, for each category of text, in Appendix A to this report. In these Appendix A tables, the mean of the four category values at each decile level is shown as an "overall" value. For each decile on each measure, the set of overall decile values may be taken as the best description of the occurrence of the measured variables in Air Force technical literature in general.

Measurement of Variables in Non Air Force Literature

Data describing the occurrence of the psycholinguistic and SI oriented variables in common literature were calculated in order to compare the characteristics of Air Force and civilian writing. For these purposes, a sample of passages was sought which would reflect the writing styles characteristic of popular and technical writing. Three passages of approximately 100 words were randomly selected from: (1) each of two popular novels, (2) a popular periodical, (3) a junior high school mathematics text, (4) a high school physics text, and (5) a technical journal containing articles by contemporary scientists. Each passage began at the beginning of a sentence and ended at the first sentence end following the 99th successive word of running text. This, as well as all other details of sample selection procedure, paralleled the procedures followed in the selection of the Air Force text samples. Table 4 presents the sources of this sample, which is referred to as the "general" sample in subsequent sections of this report.

Results of Analysis of General Sample

As in the previous analysis, the obtained comprehensibility values were rank ordered by magnitude. A table of values, based on these 18 samples, is presented as Table A-15 of Appendix A.

Table 4

Sources of Samples of General Writing

Steinbeck, J. Cannery Row. New York: Viking Press, 1945.

Hemingway, E. For Whom the Bell Tolls. New York: Charles Scribner's Sons, 1940.

Reader's Digest. January 1974.

Gundlach, B., Buffie, E.G., Denny, R.R., & Kempf, A.F. Junior High School Mathematics 8. River Forest, Ill.: Laidlaw Brothers, 1968.

White, H.E. Physics, An Exact Science. New York: Van Nostrand, 1959.

Willis, M.S., Shen, M., & Gray, K.J. Canadian Journal of Chemical Engineering, 1974, 52, 331-337.

Discussion

The cumulative percentile values obtained for each variable through the measurement of the Air Force and the general sample variables are plotted in Figures 2 through 15. While the data points describing the occurrence of the variables in the general text sample are based on a relatively small sample compared with that for the Air Force material, the comparison of the corresponding distributions is of interest. In reviewing these figures, it should be noted that the scales of the abscissas vary.

Structure-of-Intellect Oriented Variables

Figure 2 indicates a consistently higher ($p < .01$, sign test) (more comprehensible) level of CMU for the Air Force materials as compared with the general literature. The relative restriction of vocabulary diversity in the Air Force samples may reflect the technical nature of the materials sampled. The subject of technical material changes rarely. Accordingly, new sets of nouns may be less often introduced than in more popular materials.

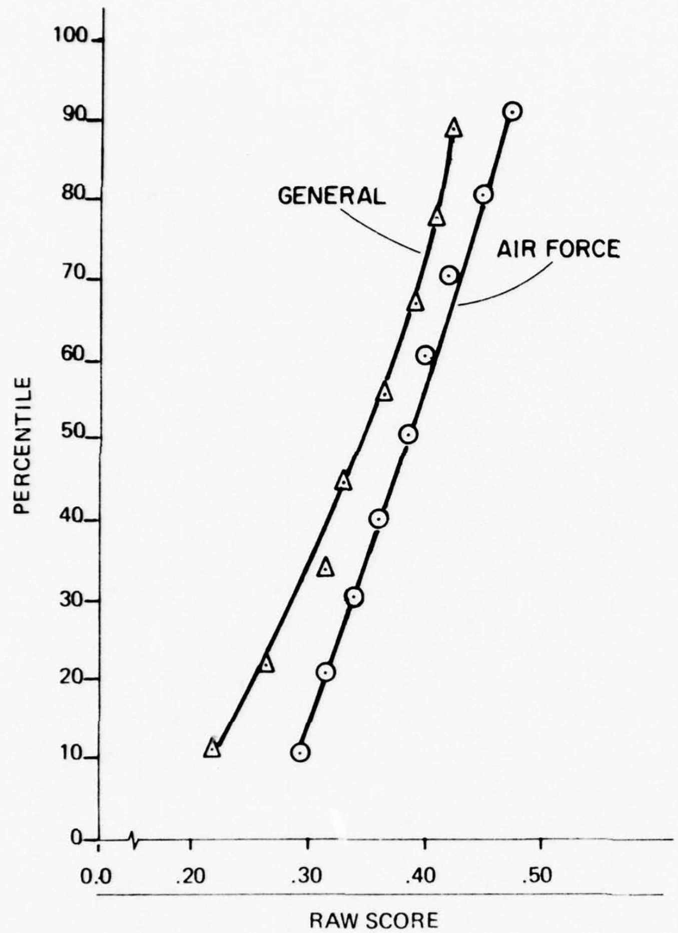

FIGURE 2. PERCENTILES CORRESPONDING TO RAW SCORES OF CMU VARIABLE IN AIR FORCE AND GENERAL TEXT SAMPLES

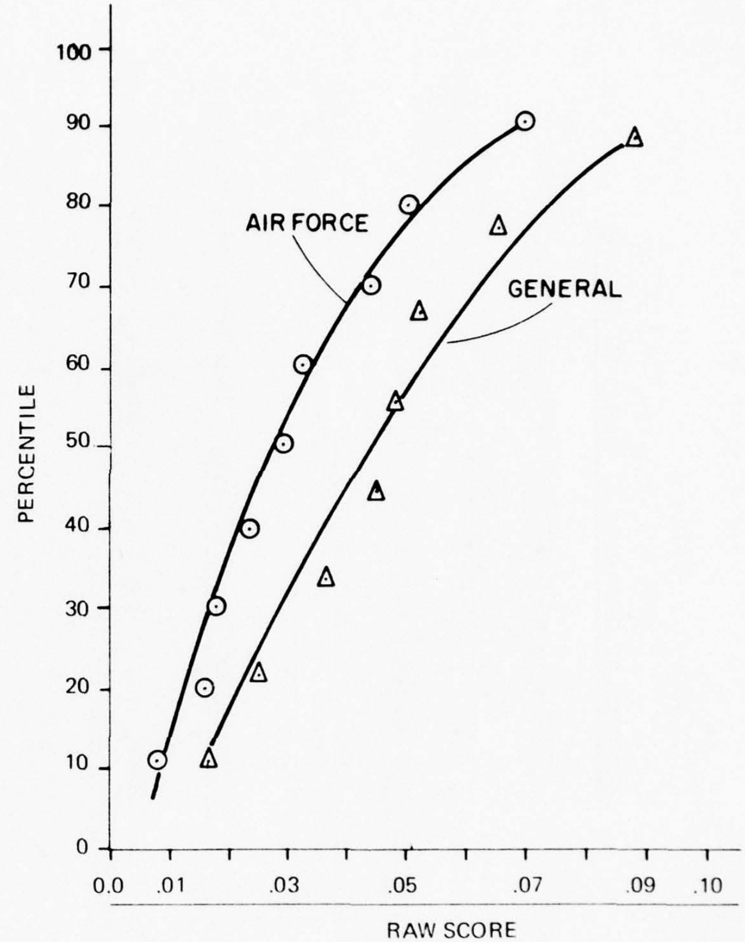

FIGURE 3. PERCENTILES CORRESPONDING TO RAW SCORES OF CMR VARIABLE IN AIR FORCE AND GENERAL TEXT SAMPLES

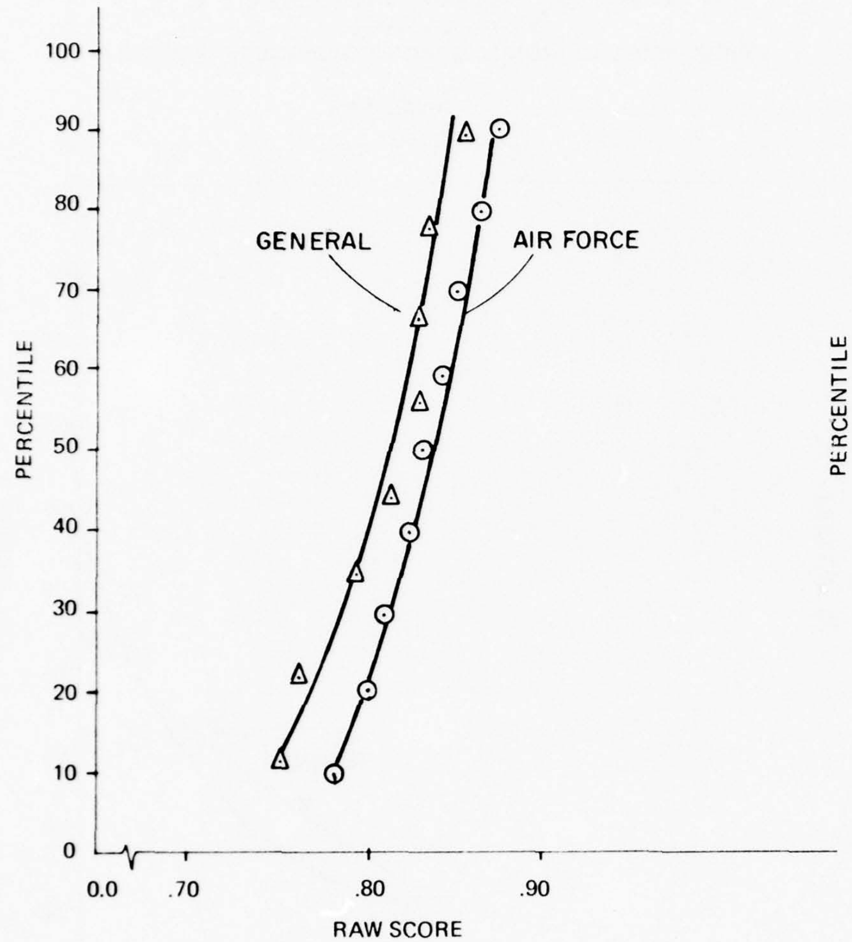

FIGURE 4. PERCENTILES CORRESPONDING TO RAW SCORES
OF MMU VARIABLE
IN AIR FORCE AND GENERAL TEXT SAMPLES

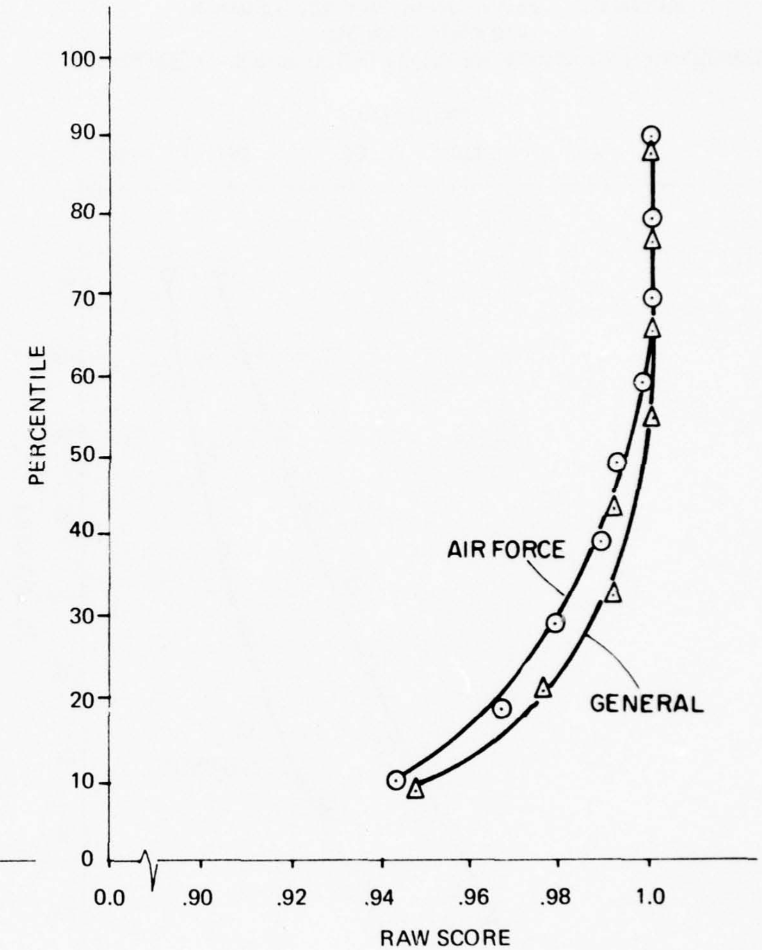

FIGURE 5. PERCENTILES CORRESPONDING TO RAW SCORES
OF ESI VARIABLE
IN AIR FORCE AND GENERAL TEXT SAMPLES

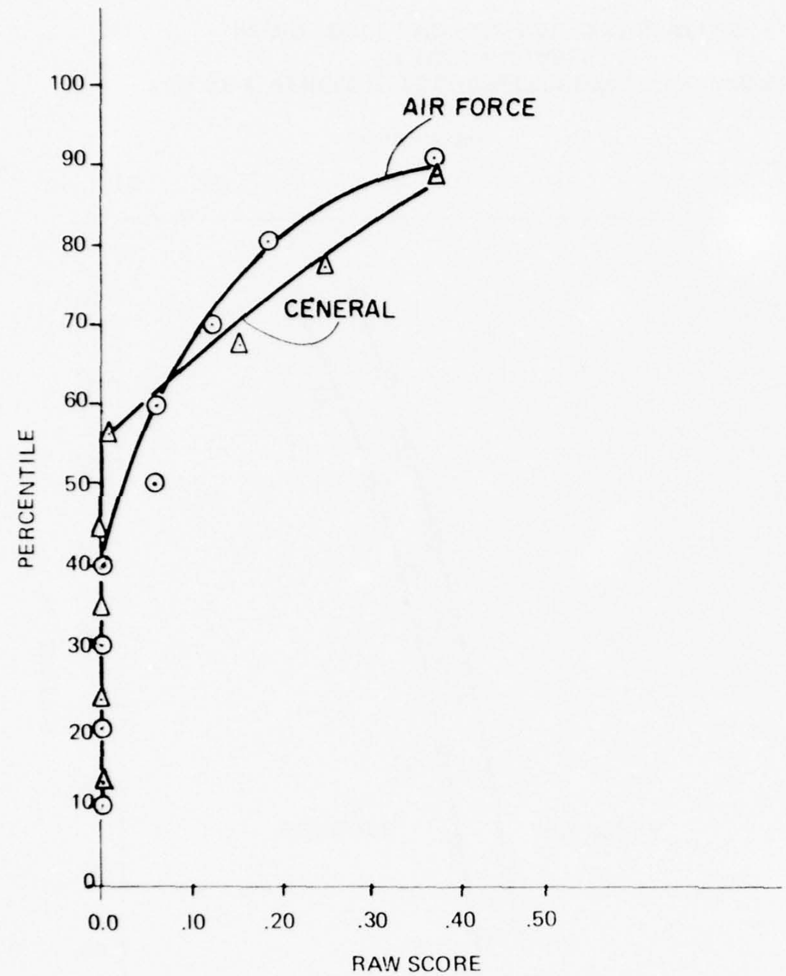

FIGURE 6. PERCENTILES CORRESPONDING TO RAW SCORES OF NMS VARIABLE IN AIR FORCE AND GENERAL TEXT SAMPLES

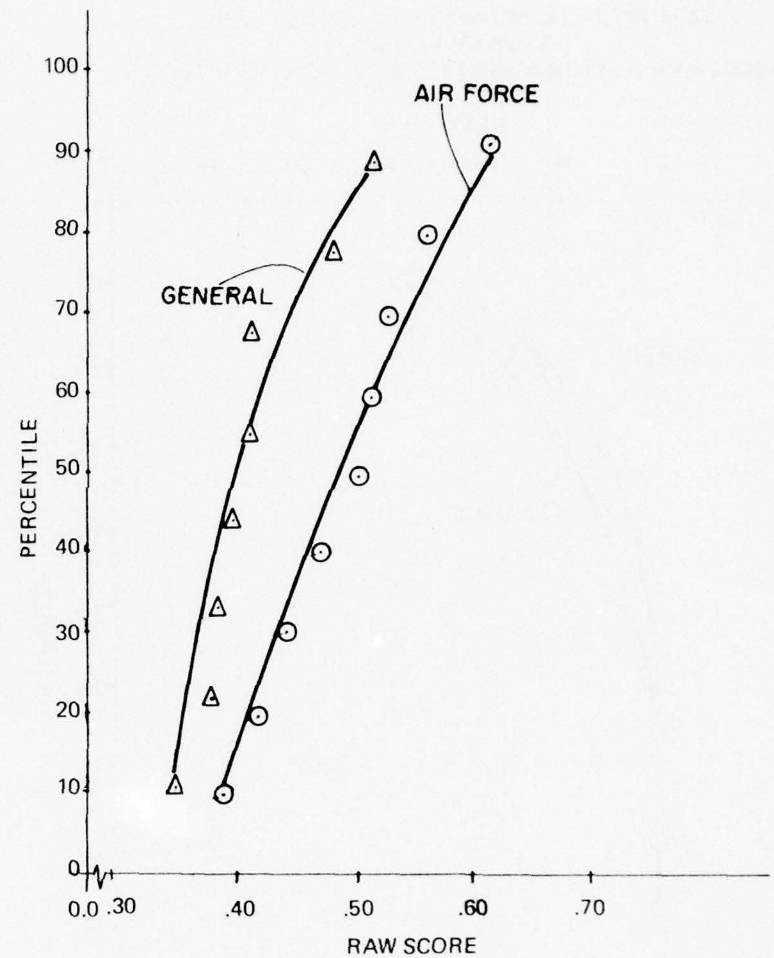

FIGURE 7. PERCENTILES CORRESPONDING TO RAW SCORES OF NMI VARIABLE IN AIR FORCE AND GENERAL TEXT SAMPLES

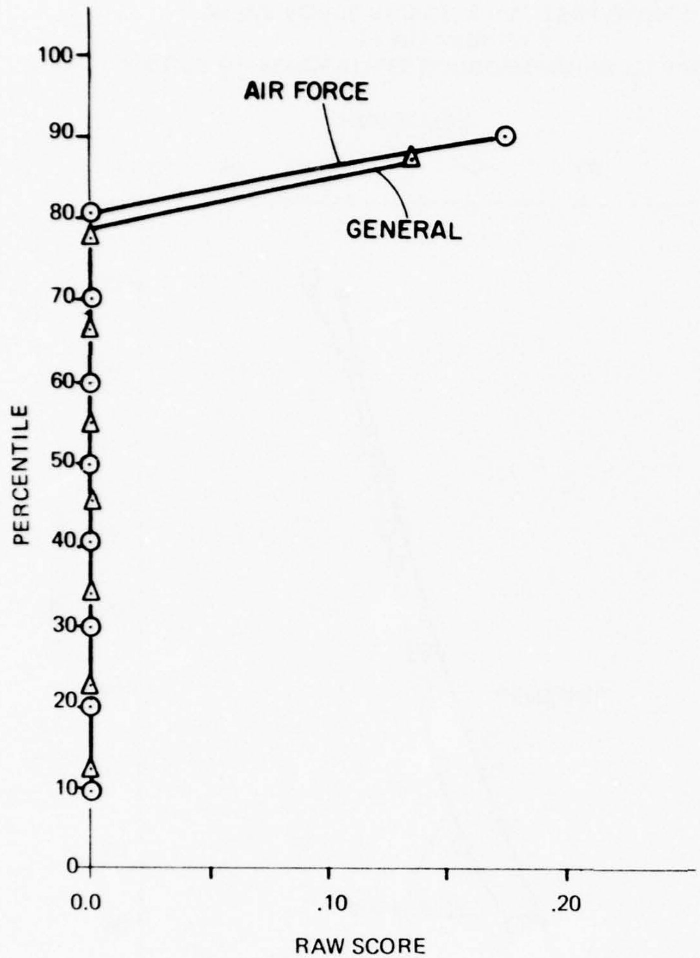

FIGURE 8. PERCENTILES CORRESPONDING TO RAW SCORES
OF DMU VARIABLE
IN AIR FORCE AND GENERAL TEXT SAMPLES

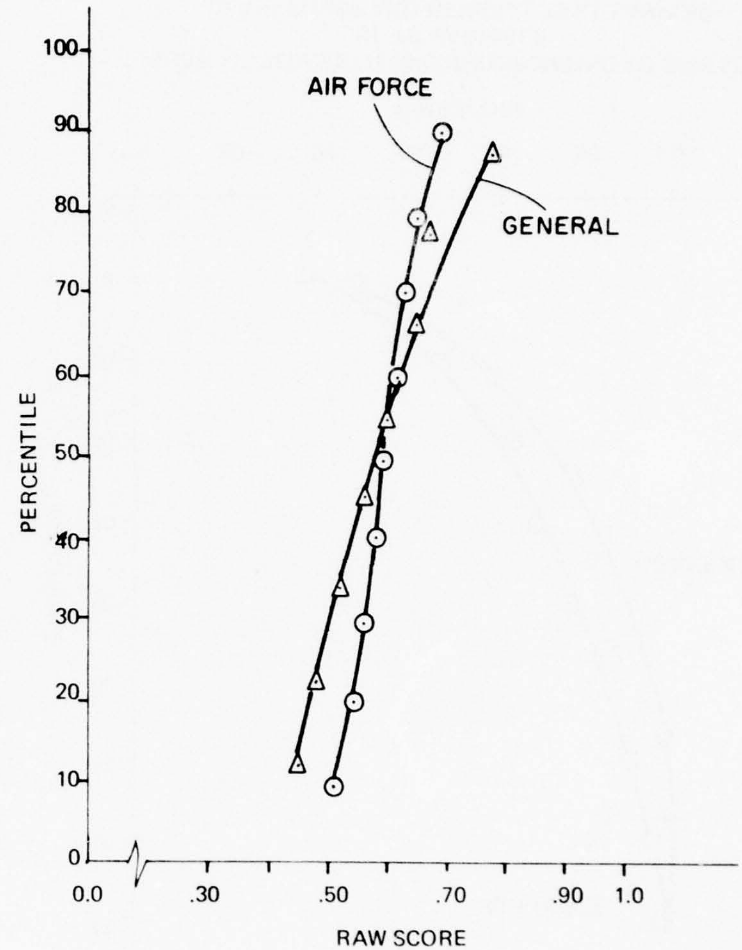

FIGURE 9. PERCENTILES CORRESPONDING TO RAW SCORES
OF YD VARIABLE
IN AIR FORCE AND GENERAL TEXT SAMPLES

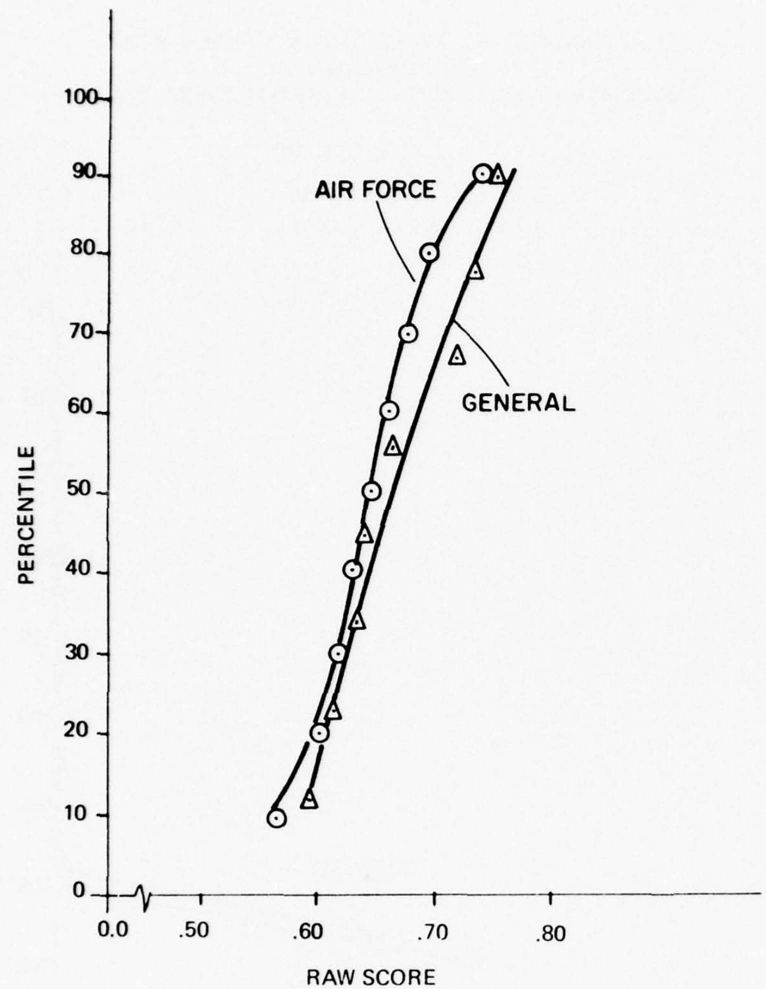

FIGURE 10. PERCENTILES CORRESPONDING TO RAW SCORES OF MD VARIABLE IN AIR FORCE AND GENERAL TEXT SAMPLES

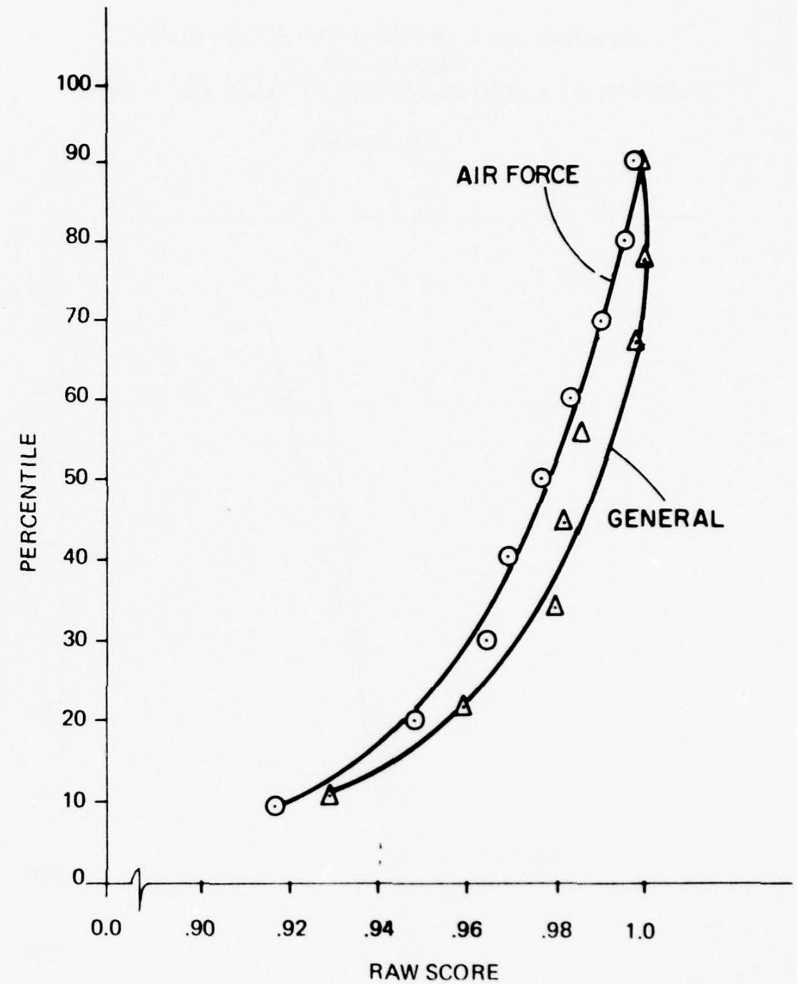

FIGURE 11. PERCENTILES CORRESPONDING TO RAW SCORES OF TC VARIABLE IN AIR FORCE AND GENERAL TEXT SAMPLES

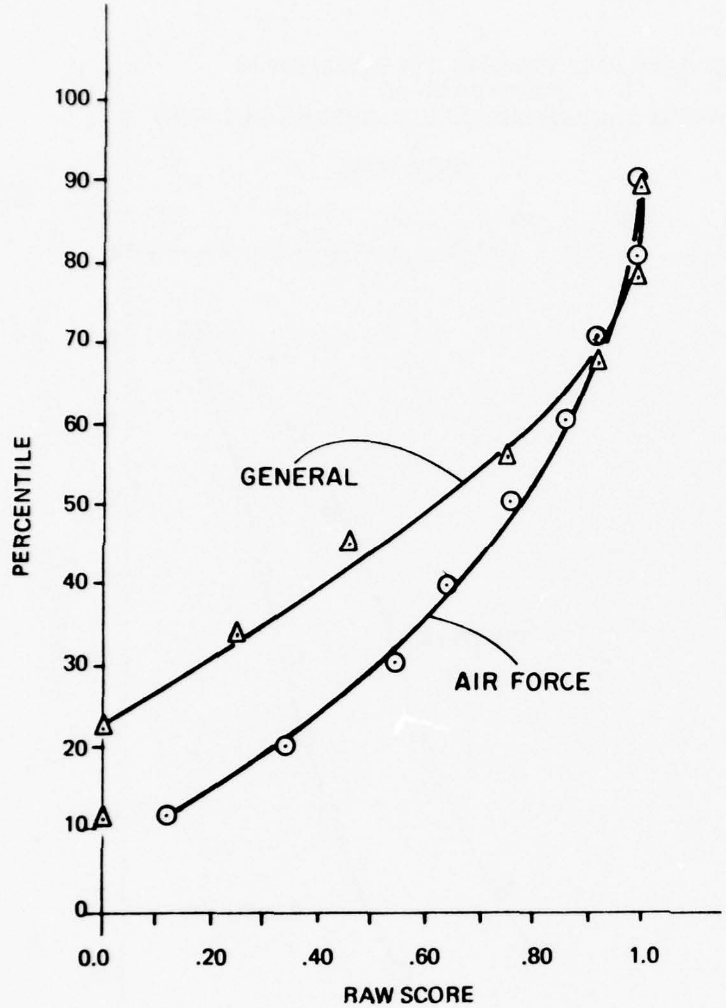

FIGURE 12. PERCENTILES CORRESPONDING TO RAW SCORES OF CE VARIABLE IN AIR FORCE AND GENERAL TEXT SAMPLES

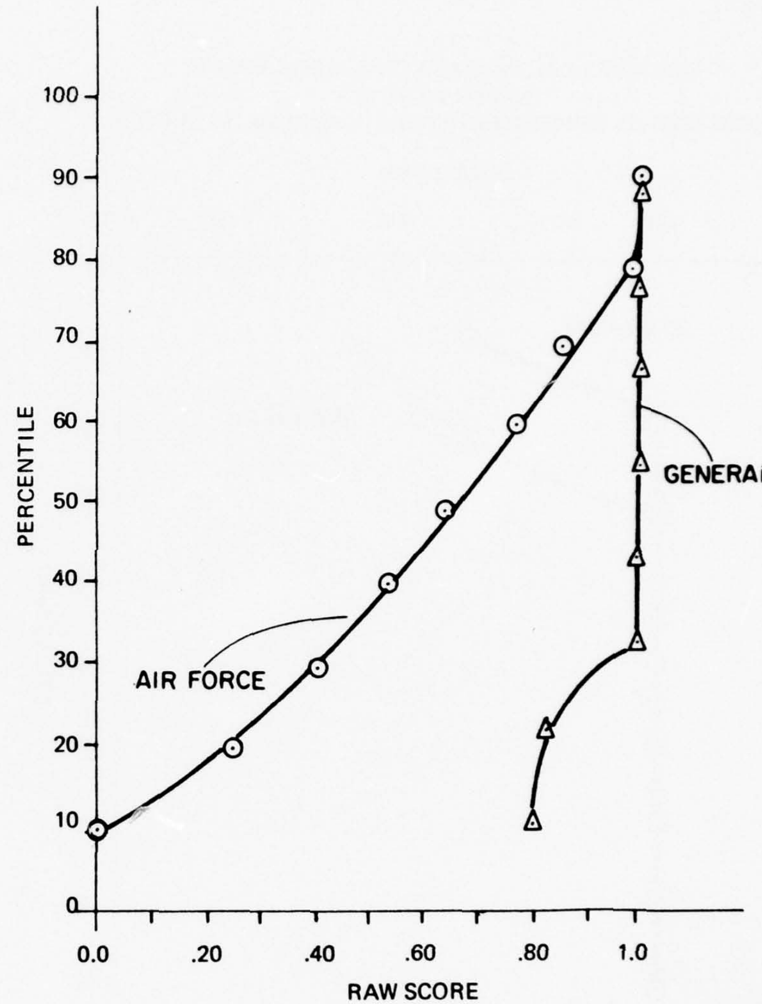

FIGURE 13. PERCENTILES CORRESPONDING TO RAW SCORES OF LB VARIABLE IN AIR FORCE AND GENERAL TEXT SAMPLES

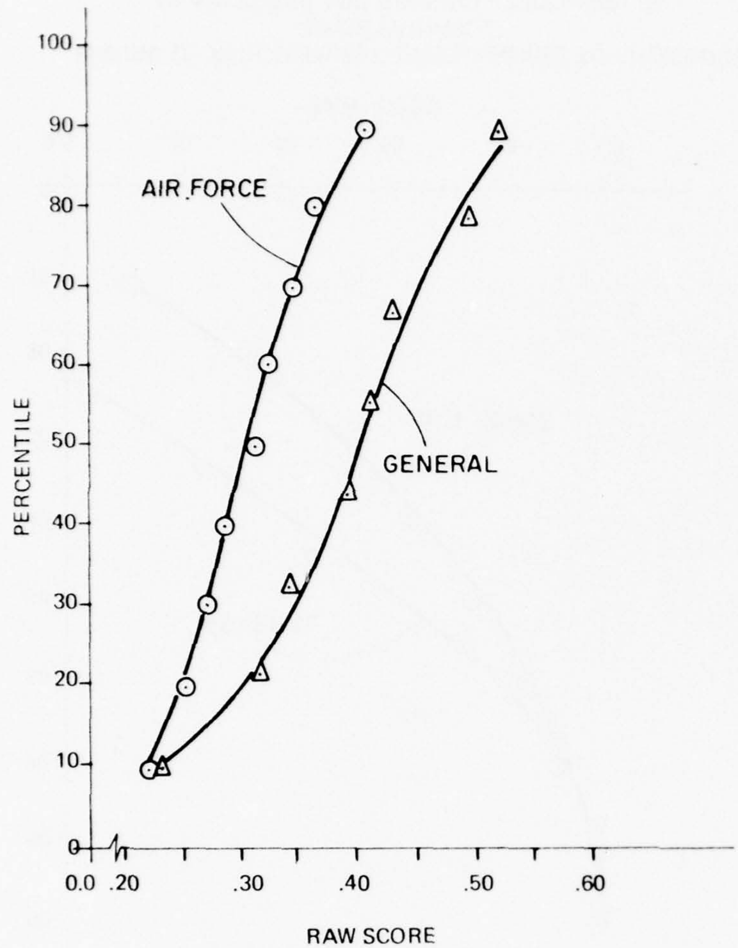

FIGURE 14. PERCENTILES CORRESPONDING TO RAW SCORES
OF RB VARIABLE
IN AIR FORCE AND GENERAL TEXT SAMPLES

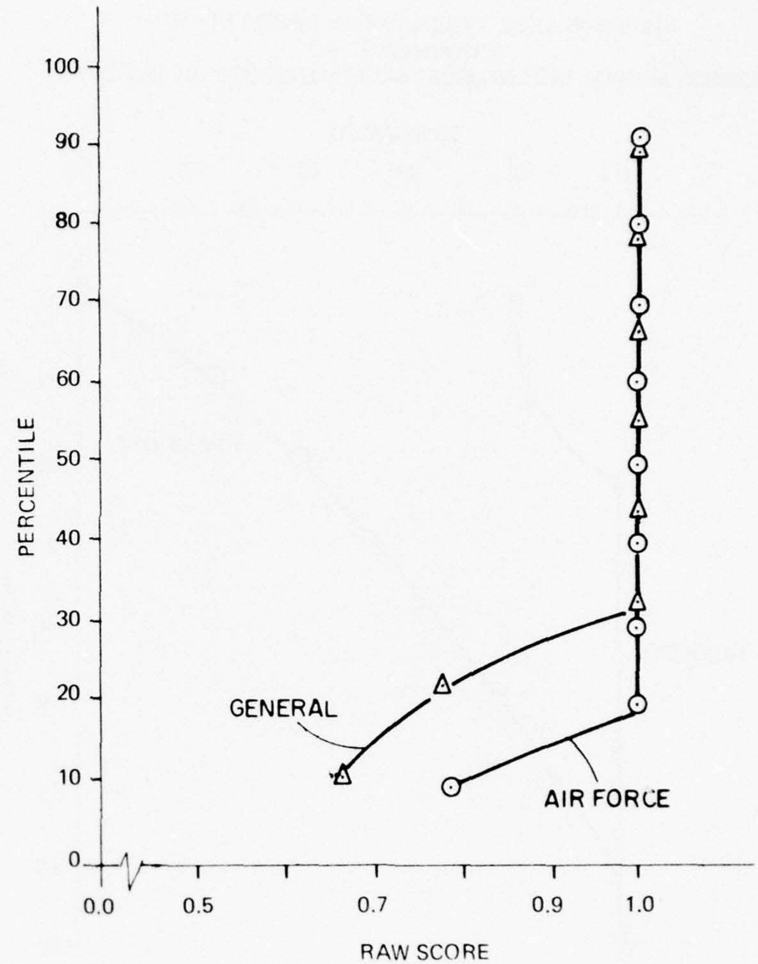

FIGURE 15. PERCENTILES CORRESPONDING TO RAW SCORES
OF DC VARIABLE
IN AIR FORCE AND GENERAL TEXT SAMPLES

The plots of CMR (Figure 3) in the general and in the Air Force materials were rather similar, although the Air Force materials are suggested by the plots to be slightly more difficult ($p < .01$, sign test).

As indicated in Figure 4, the two samples examined were quite similar in level of MMU. The Air Force materials presented slightly less mental load ($p < .01$, sign test) through this variable. This relationship is consistent with that of CMU and might be expected on the basis of the similarity of the measurement formulas.

The ESI plots of Figure 5 are nearly identical with some trend towards less difficulty for the Air Force materials ($p < .05$, sign test). The ESI measure reflects the frequency of occurrence of abbreviations. In each sample, nearly half of the passages were free of abbreviations. The most difficult (by this index) general samples appeared to show a higher frequency of abbreviations than did the most difficult Air Force passages.

The general sample and the Air Force sample were about equivalent in terms of aids to comprehension (NMS). This finding ($p > .05$, sign test) (Figure 6) was not anticipated because one would expect more explanatory information in passages developed for training purposes.

NMI considers the number of parts of speech of the individual words in a passage. As indicated in Figure 7, the Air Force technical writing tended to be easier ($p < .01$, sign test) than the general sample on this index.

The Air Force and the general samples were nearly identical ($p > .10$, sign test) in terms of DMU (a measure of the occurrence of examples), as indicated by Figure 8. Roughly 20 percent of the passages in each group contained examples which were hypothesized to aid the reader's comprehension. (A mean value of 0.0 may be obtained only if the individual values averaged are equal to 0.0, indicating an absence of examples in the averaged group.)

Psycholinguistically Oriented Variables

As measured by Yngve depth (YD), the curves for the two samples crossed. The sign test indicated no statistically significant difference ($p > .05$). These data are graphed in Figure 9.

Figure 10 shows the comparable plots relative to the morpheme depth (MD) variable. The general materials seem to be easier ($p < .05$, sign test) in this regard.

The sample of general materials demonstrated higher ($p < .01$, sign test) transformational complexity (TC) scores than the comparative Air Force sample. Figure 11 indicated that one-third of the general passages were entirely composed of active sentences. The active sentence received the highest transformational complexity score. (A passage can only receive a TC score of 1.0 if all of its sentences are active. Similarly, for a group mean to equal 1.0, all values contributing to the mean must equal 1.0.) Less than 10 percent of the Air Force samples were entirely composed of active sentences. Of the six popular passages in which all sentences were active, five were from the Reader's Digest, the writings of Hemingway, and the writings of Steinbeck.

The Air Force materials tended to be about equivalent ($p > .5$, sign test) to the popular samples in center embedded (CE) phrases (Figure 12). However, the proportions of each type of passage which were free of center embedded material were equivalent. (Mean value of 1.0 reflects an absence of center embedded material in the averaged materials.)

Approximately two-thirds of general passages were free of left branching material as indicated by values of 1.0 for the 33rd and all higher percentiles. Only 20 percent of the Air Force passages were similarly unencumbered. The sign test indicated statistical significance at the .01 level of confidence. Additionally, the general passages exhibiting left branching material did so to a far lesser degree than the Air Force materials (Figure 13). Left branching is generally due to clauses which modify the subject of a sentence. The high rate of occurrence of left branching in the Air Force materials may reflect the preponderance of part names with multiple modifiers found in technical materials.

As indicated by Figure 14, the most difficult passages in the two sets were equivalent in terms of right branching, but the less difficult Air Force sample passages were not improved in terms of right branching as much as were the less difficult general passages. That is, at equivalent percentile values, the Air Force sample exhibited a lower RB score ($p < .01$, sign test) than did the general sample.

As shown in Figure 15, a majority of both groups of passages was found free of deleted complements. The sign test indicated no statistically significant difference between the two samples.

In addition, duMas' coefficient of profile similarity (Mosel & Roberts, 1954) was computed to compare the shapes of the distributions of the 14 variables in the Air Force and in the general sample. The value profiled was the percentile score of each distribution which corresponded to the value of the mean of the values making up that same distribution.

Profiles composed of the measures described were constructed for the Air Force sample and for the general sample. The variables were placed in the order in which they were defined in the present chapter. The obtained duMas coefficient of profile similarity was .66. Since this statistic may range from -1.0 to +1.0, the obtained value indicates substantial similarity in the profiles. Although the various profiles are modestly displaced from each other, they are quite similar in form; the primary difference was in the magnitude of the raw scores.

III. DEVELOPMENT OF A REGRESSION EQUATION AND CROSS-VALIDATION

As indicated in Chapter I, prior studies have resulted in the development of a set of psycholinguistic and SI oriented variables. However, the actual predictive power of these variables has not been established for the variables singly or in combination. Hence, the research described in this chapter was intended to generate a comprehensibility equation that could be used to predict the difficulty of passages of textual material.

Subjects

Two groups of subjects were involved. One group (non high school graduates) represented low reading ability and the other (college students) represented high reading ability. The low reading ability group was composed of 30 paid, volunteer subjects who were students in a technical job training program. The high reading ability group was composed of 21 similarly paid volunteer college undergraduate students.

The distribution of the Nelson-Denny Reading Test scores and corresponding reading grade levels of each subject group is shown in Figure 16. The total group is divided into low- and high-reading level groups at the 10.0 reading grade level. The low reading level group contains the lower scoring 26 of the subjects obtained through the job training program. The high reading level group contains four subjects from the job training group who scored above the 10.0 grade level on the Nelson-Denny test, as well as the 21 college undergraduates.

Passage Selection

The comprehensibility equation development was based on a set of passages selected from Air Force Career Development Course (CDC) texts. CDCs are uniquely characterized among Air Force technical publications by a predominance of connected prose. In CDCs, textual characteristics such as outlines and numbered lists of procedural steps (which are quite common in study guides, technical orders, and manuals) are relatively rare.

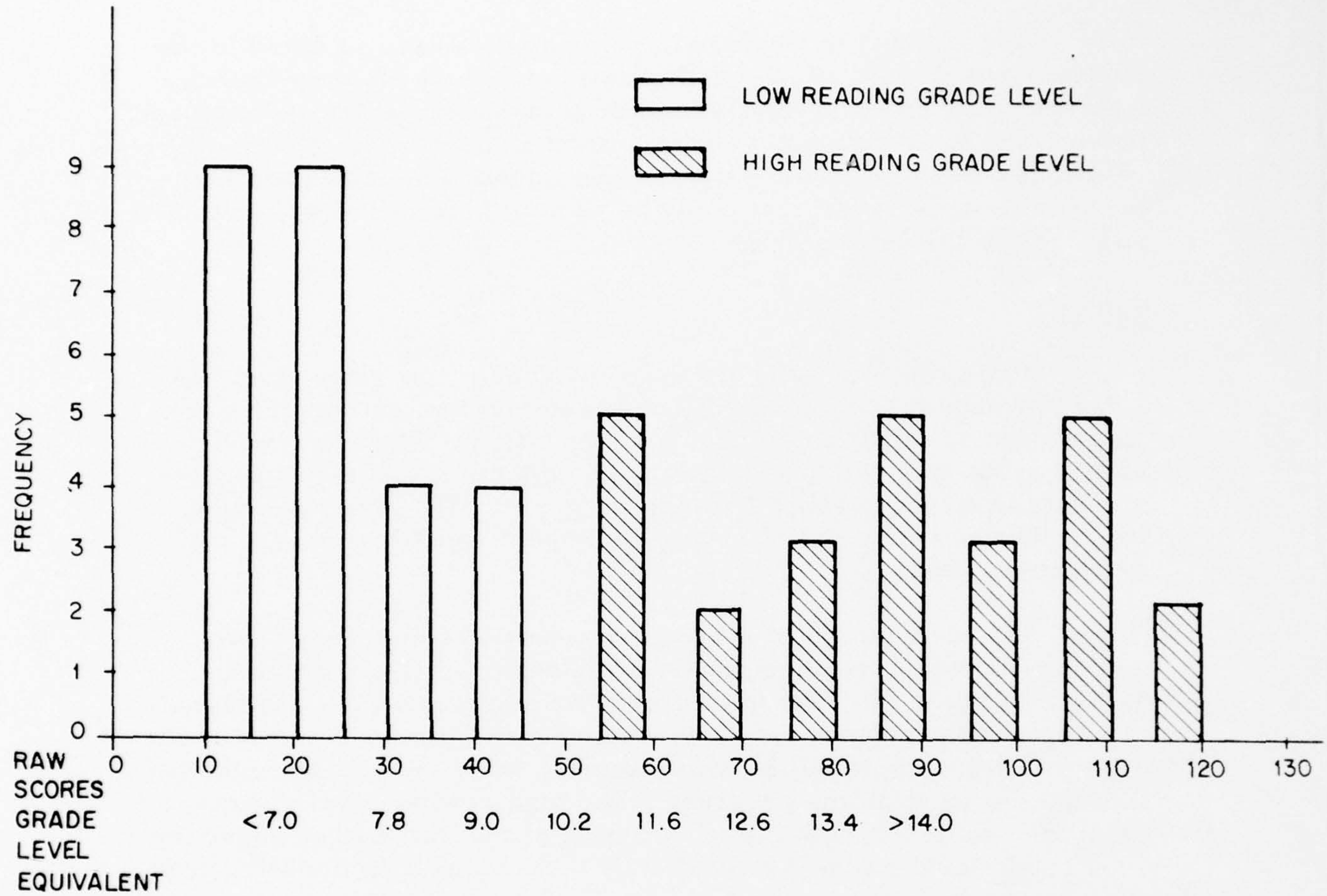

FIGURE 16. DISTRIBUTION OF NELSON-DENNY RAW SCORES AND GRADE LEVEL EQUIVALENTS OF LOW AND HIGH GRADE LEVEL SUBJECT GROUPS

Fourteen CDC text passages were selected from three sets of texts. These text sets are listed in Table 5.

Table 5

CDCs Sampled for Predictive Study

CDC 43151C	Aircraft Maintenance Specialist, Jet Aircraft, One and Two Engines
CDC 43113	Aircraft Mechanic
CDC 64550	Inventory Management Specialist

The passages were taken at equal intervals through the total number of column pages contained in the three sets of texts. The procedure followed duplicated that employed for selection of the Air Force normative sample, described in Chapter II. Through this procedure, three samples were selected from CDC 43151C, five from CDC 43113 and six from CDC 64550. Each passage was of such length as to contain six blocks of roughly 100 words of prose. The word count for each block began at the beginning of a sentence and continued until the first sentence end following the 99th successive word.

Preparation of Stimulus Materials

Cloze test forms were prepared from each passage by deleting every 10th word. The first word deleted in each passage was a random selection from the first ten words of the passage. Cloze test forms were typed in double-spaced format. No deletions were made to subheads. Figures, diagrams, or tables referenced in the passages were not shown, since the variables under investigation are only measured in connected prose. Test booklets were then assembled so that each booklet contained all 14 passages and the order of appearance of passages within booklets was individually randomized.

Cloze Test Scoring

Taylor (1953), in initially presenting the cloze procedure, reported that the procedure is not sensitive to the scoring criteria employed. According to Taylor, the resultant ordering of passage scores is not changed if synonyms of deleted words are accepted as correct or if only precise matches are accepted. In the current work, a relatively strict scoring procedure was followed:

- only precise matches of deleted words or matches involving obvious errors of spelling, tense, or number were accepted as correct;
- if a number was required (e.g., a table or figure number, model number) any number, whether entered as digits or written out, was accepted.

In all cases, cloze test scores are reported as percentage of deleted words correctly entered, according to the criteria described above. This is the "normal" cloze score.

Procedure

Data collection required a period of approximately six hours. All subjects were initially administered the Nelson-Denny Reading Test (Revised), Form A (Brown, 1960). Instructions were then presented relative to the procedures to be followed for completing the cloze passages. The subjects were allowed 18 minutes to work on each passage. They were instructed to proceed to a subsequent passage only at the completion of an 18-minute time block, and not to go back to an earlier passage after the completion of its work period. A pilot test indicated that this work rate allowed sufficient time for subjects to complete each passage, while ensuring that subjects did not dwell excessively on difficult items. A 10-minute break was taken after every four passages. The test session for the job training group subjects was additionally broken by a one-hour lunch break. The college subjects took the Nelson-Denny test and six cloze passages on one test day, and the remaining eight cloze passages on the succeeding day.

Predictor Data

The level of each of the psycholinguistic and the SI oriented variables in each of the six blocks of each of the 14 passages represented the predictors required. These variables were measured exactly as they had been during the collection of normative data, and the same group of analysts who collected the normative data performed the required analyses. The percentile levels of the 14 variables, as shown in the developed norms, were tabulated separately for each block of each passage, and then averaged over the passage.

Data Analysis and Results

A conventional cross-validation approach was used to accomplish the objective noted above. Since each of the 51 subjects obtained a cloze score on each of 14 passages, the data were regarded as 14 x 51 = 714 observations to be regressed on the 14 independent variables (comprehensibility measures). Thus, the matrix that was used in the multiple regression analysis was 714 x 15. However, since this matrix contains unwanted subject effects, the analysis was preceded by partialing out these effects. This was accomplished by constructing a design matrix representing between subject effects and partialing it out of the 714 x 15 matrix. The resulting matrix contains variance attributable to passages only, and thus is appropriate for the analysis described below.

The subject pool was randomly divided into halves and a multiple step-wise regression analysis was performed on the data for each half (designated as H1 and H2). Each equation thus derived was then applied to the data from the other half of the sample and the multiple Rs were observed for shrinkage. The validities resulting from this procedure are presented in Table 6. Referring to the table, the reader can see that the multiple R derived from the H1 data dropped by only .083 when the equation was applied to the H2 data; and that derived from the H2 half did not diminish at all when the equation was applied to H1. Since the shrinkage of the validities was negligible, a regression analysis was performed on the combined data. This analysis yielded the following equation:

$$\text{Estimated Cloze} = .169\text{CMU} - .173\text{MMU} + .156\text{ESI} + .19\text{DMU} + .335\text{YD} + .26\text{TC} - .14\text{CE} + .242\text{RB} - .344,$$

in which each of the comprehensibility measure values is in the form of percentiles taken from the norm tables in Appendix A of this report. The cloze score derived from this equation is an estimate of the traditional cloze value; i. e., the percentage of deletions from the text that are correctly filled in.

Table 6

Validities of Equations Developed on Both Halves of the Sample and the Total Sample

	Total	H1	H2
Total	.601		
H1		.598	.515
H2		.599	.592

While the reader who is interested in determining the comprehensibility of text would probably use the above equation, it seemed of interest to compute comparable equations for each of the two reading ability groups. Table 7 presents the weights for each of the variables of the equations in the order in which they were added to the regression equation and the constants associated with each equation. It may be noted that MMU, ESI, and YD were the first three factors for each equation, as they did when all the data were combined. Even though most of the variance is accounted for by these three factors a noteworthy observation is the occurrence of only two common factors among the remaining measures in the equations, and the reversal of signs for MMU and MD between ability groups. This may mean that low and high ability groups process information differently and are differentially able to cope with the comprehensibility factors. Of course, these differences between high and low groups may also be sample specific and should be replicated. A complete explanation of these findings awaits further research.

Table 7

Regression Equations for Low and High RGL Groups

Low RGL Group	High RGL Group
.132 MMU	-.332 MMU
.164 ESI	.171 ESI
.200 YD	.418 YD
-.207 CE	.397 TC
.250 RB	.302 CMU
-.151 MD	.089 MD
-.289 NMI	.320 DMU
-.074 LB	.167 RB
-.003(Intercept)	-.509(Intercept)

Discussion

The work reported in Chapter III was completed in order to: (1) provide additional verification of psycholinguistically and SI oriented variables as measures of textual comprehensibility, and (2) provide a method for predicting the comprehensibility of textual materials. Both of these goals, established at the outset, seem to have been achieved.

In this regard, we note that the materials on which the current effort was based should be considered in the evaluation of the multiple correlation for the regression equation. Predictions of comprehensibility have customarily been established using written materials which extend across a wide range of reading difficulty, such as Grades 3-12, Grade 4 - College, Grade 1 - Professional, etc. The materials used here were all technical materials of high content difficulty and intended for adult readers.

Such a restriction of range in the criterion would be expected to attenuate the multiple correlation. Nonetheless, the obtained multiple correlation value of .601 was acceptable. Accordingly, increased confidence, in the value of the variables is afforded by these results.

IV. DISCUSSION AND CONCLUSIONS

The present work was performed to extend and verify prior work relative to a set of psycholinguistically and SI oriented variables as they affect the comprehensibility of textual materials. In the work performed, norms and a multiple linear regression equation relating selected psycholinguistically and SI oriented variables to textual comprehensibility were derived, and a conventional cross-validation was performed.

Traditionally, the developers of readability equations have warned against employing such equations in reverse as "rules for writing." Throughout the development and investigation of the characteristics of the psycholinguistic and the SI oriented variables, it has been held that the present variables possess diagnostic and prescriptive, as well as descriptive, value. These arguments seem supported on the bases that the present variables consider the linguistic and the intellective processes involved in written language decoding. There was little, if anything, in the present work to negate the contentions of the prior work relative to the value of the psycholinguistic and the SI oriented variables for comprehensibility measurement, prediction, and improvement.

On the basis of the data and results of the present work, the following conclusions seem warranted:

1. Norms describing the characteristics of a variety of Air Force technical materials on a set of psycholinguistically and SI oriented variables are now available;

2. An equation relating the psycholinguistically and the SI oriented variables to comprehensibility (cloze score) is now available.

REFERENCES

Bormuth, J.R. Readability, A new approach. *Reading Research Quarterly*, 1966, *1*, 79-132.

Bormuth, J.R. *Development of readability*. (Final Project Report No. 7-0052) Washington, D.C.: Department of Health, Education and Welfare, 1969.

Brown, J.I. *The Nelson-Denny reading test. Vocabularly, comprehension rate.* (revised) Form A. Boston, Mass.: Houghton-Mifflin, 1960.

Coleman, M., & Liau, T.L. A computer readability formula designed for machine scoring. *Journal of Applied Psychology*, 1975, *60*, 283-284.

Guilford, J.P. *The nature of human intelligence.* New York: McGraw-Hill, 1967.

Guilford, J.P., Comrey, A.L., Green, R.F., & Christensen, P.R. *A factor analytic study of reasoning abilities. I. Hypotheses and description of tests.* Los Angeles: University of Southern California, 1950.

Guilford, J.P., Geiger, R.M., & Christensen, P.R. *A factor analytic study of planning. I. Hypotheses and description of tests.* Los Angeles: University of Southern California, 1954.

Guilford, J.P., & Hoepfner, R. *Structure-of-intellect factors and their tests.* Los Angeles: University of Southern California, 1966.

Guilford, J.P., & Hoepfner, R. *The analysis of intelligence.* New York: McGraw-Hill, 1971.

Hakes, D.T. Effects of reducing complement constructions on sentence comprehension. *Journal of Verbal Learning and Verbal Behavior*, 1972, *11*, 278-286.

Hoepfner, R., Guilford, J.P., & Merrifield, P.R. *A factor analysis of the symbolic-evaluation abilities.* Los Angeles: University of Southern California, 1964.

Lambert, J.V., & Siegel, A.I. Psycholinguistic determinants of readability. In A.I. Siegel and J.R. Burkett (Eds.) *Application of structure-of-intellect and psycholinguistic concepts to reading comprehensibility measurement.* (AFHRL-TR-74-49). Lowry AFB, Colo.: Air Force Human Resources Laboratory, September 1974.

Martin, E., & Roberts, K.H. Grammatical factors in sentence retention. *Journal of Verbal Learning and Verbal Behavior,* 1966, *5,* 211-218.

Mosel, J.N., & Roberts, J.B. The comparability of profile similarity: An empirical study. *Journal of Consulting Psychology,* 1954, *18,* 61-66.

Schwartz, D., Sparkman, J.P., & Deese, J. The process of understanding and judgments of comprehensibility. *Journal of Verbal Learning and Verbal Behavior,* 1970, *9,* 87-93.

Siegel, A.I., & Bergman, B.A. Readability/comprehensibility as related to the structure-of-intellect model. In A.I. Siegel and J.R. Burkett (Eds.), *Application of structure-of-intellect and psycholinguistic concepts to reading comprehensibility measurement.* (AFHRL-TR-74-49) Lowry AFB, Colo.: Air Force Human Resources Laboratory, September 1974. AD-A001 573.

Siegel, A.I., Federman, P.J., & Burkett, J.R. *Increasing and evaluating the readability of Air Force written materials.* (AFHRL-TR-74-28) Lowry AFB, Colo.: Air Force Human Resources Laboratory, August 1974. AD-786 820.

Siegel, A.I., Lambert, J.V., & Burkett, J.R. *Techniques for making written materials more readable/comprehensible.* (AFHRL-TR-74-47) Lowry AFB, Colo.: Air Force Human Resources Laboratory, August 1974. AD-786 849.

Siegel, A.I., Williams, A.R., Lapinsky, W.G., Warms, T.A., Wolf, J.J., Groff, S.D., & Burkett, J.R. *Studies and design specifications for computerised measurement of textual comprehensibility.* (AFHRL-TR-76-77) Lowry AFB, Colo.: Air Force Human Resources Laboratory, December 1976.

Taylor, W. Cloze procedure: A new tool for measuring readability. *Journalism Quarterly,* 1953, *30,* 415-433.

Wang, M.D. The role of syntactic complexity as a determiner of comprehensibility. *Journal of Verbal Learning and Verbal Behavior,* 1970, *9,* 398-404.

Williams, A.R., Siegel, A.I., & Burkett, J.R. *Readability of textual materials--A survey of the literature.* (AFHRL-TR-74-29) Lowry AFB, Colo.: Air Force Human Resources Lab., July 1974. Also: (MS. NO. 876) JSAS *Catalog of Selected Documents in Psychology*, 1975, *5*, 202.

Winer, B.J. *Statistical principles in experimental design.* (2nd. Ed.). New York: McGraw-Hill, 1971.

Yngve, V.H. A model and a hypothesis for language structure. *Proceedings of the American Philosophical Society*, 1960, *104*, 444-466.

APPENDIX

Tables of Norms

To aid the reader in interpreting the tables presented in this appendix an example of how Table A-1 should be read follows: ten percent of the study guide samples had a CMU value of less than .288; over all of the materials ten percent of the samples had a CMU value of less than .293. Ninety percent of the study guide samples had a CMU value of less than .470; over all the materials, ninety percent of the samples had a CMU value of less than .476.

Table A-1

Cognition of Semantic Units (CMU)

PERCENTILE	SG	MAN	CDC	TO	O/A*
90	.470	.436	.462	.534	.476
80	.450	.407	.442	.496	.449
70	.442	.390	.403	.458	.423
60	.424	.366	.374	.434	.400
50	.394	.340	.348	.430	.378
40	.373	.336	.324	.404	.359
30	.352	.312	.314	.392	.342
20	.314	.296	.300	.369	.320
10	.288	.268	.282	.334	.293

Table A-2

Cognition of Semantic Relations (CMR)

SG	MAN	CDC	TO	O/A
.067	.072	.104	.038	.070
.052	.052	.070	.024	.050
.048	.047	.062	.017	.044
.036	.034	.048	.015	.033
.032	.031	.040	.012	.029
.026	.028	.034	.009	.024
.022	.018	.026	.006	.018
.022	.014	.022	.003	.015
.017	.009	.010	.001	.008

Table A-3

Memory of Semantic Units (MMU)

PERCENTILE	SG	MAN	CDC	TO	O/A
90	.877	.866	.868	.884	.874
80	.866	.857	.852	.870	.861
70	.850	.846	.844	.858	.850
60	.842	.836	.836	.850	.841
50	.837	.822	.826	.844	.832
40	.825	.814	.819	.838	.824
30	.816	.809	.807	.821	.813
20	.800	.800	.798	.812	.802
10	.786	.772	.774	.800	.783

Table A-4

Evaluation of Symbolic Implications (ESI)

SG	MAN	CDC	TO	O/A
1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	.991	.998
.992	.996	.996	.985	.992
.991	.992	.991	.982	.989
.981	.982	.982	.971	.979
.972	.960	.998	.955	.967
.943	.936	.972	.922	.943

*SG= *Study Guides*
MAN= *Manuals*
CDC= *Career Development Course*
TO= *Technical Order*
O/A= *Overall*

[See page 49 for sample interpretation of these tables.]

Table A-5

Convergent Production of Semantic Systems (NMS)

PERCENTILE	SG	MAN	CDC	TO	O/A
90	.250	.250	.500	.500	.375
80	0.000	.250	.250	.250	.188
70	0.000	0.000	.250	.250	.125
60	0.000	0.000	0.000	.250	.062
50	0.000	0.000	0.000	.250	.062
40	0.000	0.000	0.000	0.000	0.000
30	0.000	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000

Table A-6

Convergent Production of Semantic Implications (NMI)

SG	MAN	CDC	TO	O/A
.579	.605	.580	.656	.605
.548	.550	.548	.581	.557
.525	.524	.523	.532	.526
.500	.520	.500	.524	.511
.500	.500	.478	.524	.500
.478	.478	.438	.490	.471
.444	.442	.415	.458	.440
.406	.420	.394	.438	.414
.382	.389	.368	.415	.388

Table A-7

Divergent Production of Semantic Units (DMU)

PERCENTILE	SG	MAN	CDC	TO	O/A
90	.235	0.000	.464	0.000	.175
80	0.000	0.000	0.000	0.000	0.000
70	0.000	0.000	0.000	0.000	0.000
60	0.000	0.000	0.000	0.000	0.000
50	0.000	0.000	0.000	0.000	0.000
40	0.000	0.000	0.000	0.000	0.000
30	0.000	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000

Table A-8

Yngve Depth (YD)

SG	MAN	CDC	TO	O/A
.665	.649	.705	.684	.676
.645	.623	.649	.637	.638
.632	.610	.636	.622	.625
.624	.598	.613	.606	.610
.608	.581	.595	.578	.590
.594	.565	.571	.558	.572
.571	.552	.559	.552	.558
.548	.532	.534	.537	.538
.516	.506	.499	.512	.508

[See page 49 for sample interpretation of these tables.]

Table A-9

Morpheme Depth (MD)

PERCENTILE	SG	MAN	CDC	TO	O/A
90	.759	.712	.732	.764	.742
80	.704	.666	.706	.706	.696
70	.668	.654	.690	.690	.676
60	.655	.644	.681	.671	.663
50	.640	.636	.652	.660	.647
40	.626	.612	.640	.643	.630
30	.612	.596	.628	.634	.618
20	.594	.584	.613	.617	.602
10	.560	.510	.600	.600	.568

Table A-10

Transformational Complexity (TC)

SG	MAN	CDC	TO	O/A
.994	.997	1.000	1.000	.998
.990	.989	1.000	1.000	.995
.986	.981	.994	1.000	.990
.979	.970	.992	.990	.983
.970	.966	.984	.988	.977
.967	.960	.980	.975	.970
.960	.950	.974	.971	.964
.947	.923	.960	.964	.948
.893	.873	.946	.957	.917

Table A-11

Center Embeddedness (CE)

PERCENTILE	SG	MAN	CDC	TO	O/A
90	1.000	1.000	1.000	1.000	1.000
80	1.000	1.000	1.000	1.000	1.000
70	1.000	.833	.866	1.000	.925
60	.857	.800	.845	1.000	.876
50	.800	.690	.732	.800	.756
40	.667	.600	.667	.586	.630
30	.600	.500	.586	.464	.538
20	.500	.292	.333	.200	.331
10	.325	.000	.167	.000	.123

Table A-12

Left Branching (LB)

SG	MAN	CDC	TO	O/A
1.000	1.000	1.000	1.000	1.000
.944	1.000	1.000	1.000	.986
.833	.817	.775	1.000	.856
.800	.708	.667	.866	.760
.714	.500	.600	.690	.626
.589	.414	.500	.600	.526
.400	.387	.310	.464	.390
.333	.250	.167	.250	.250
0.000	0.000	0.000	0.000	0.000

[See page 49 for sample interpretation of these tables.]

Table A-13

Right Branching (RB)

PERCENTILE	SG	MAN	CDC	TO	O/A
90	.400	.382	.412	.425	.405
80	.372	.333	.372	.392	.367
70	.358	.312	.357	.362	.347
60	.333	.297	.333	.342	.326
50	.324	.286	.308	.322	.310
40	.294	.250	.286	.312	.286
30	.274	.244	.256	.308	.270
20	.244	.233	.227	.286	.248
10	.224	.196	.208	.250	.220

Table A-14

Deleted Complement (DC)

PERCENTILE	SG	MAN	CDC	TO	O/A
90	1.000	1.000	1.000	1.000	1.000
80	1.000	1.000	1.000	1.000	1.000
70	1.000	1.000	1.000	1.000	1.000
60	1.000	1.000	1.000	1.000	1.000
50	1.000	1.000	1.000	1.000	1.000
40	1.000	1.000	1.000	1.000	1.000
30	1.000	1.000	1.000	1.000	1.000
20	1.000	1.000	1.000	1.000	1.000
10	.938	.800	.829	1.000	.892

[See page 49 for sample interpretation of these tables.]

Table A-15

SI Variables--General Literature

PERCENTILE	CMU	CMR	MMU	ESI	NMS	NMI	DMU
90	.426	.089	.857	1.000	.375	.508	.133
80	.410	.070	.841	1.000	.273	.483	0.000
70	.383	.056	.833	1.000	.159	.426	0.000
60	.366	.049	.830	1.000	.045	.407	0.000
50	.349	.046	.822	.996	0.000	.402	0.000
40	.331	.042	.807	.991	0.000	.390	0.000
30	.308	.034	.788	.987	0.000	.376	0.000
20	.267	.023	.765	.973	0.000	.365	0.000
10	.228	.017	.754	.947	0.000	.350	0.000

Psycholinguistic Variables--General Literature

PERCENTILE	YD	MD	TC	CE	LB	RB	DC
90	.781	.758	1.000	1.000	1.000	.542	1.000
80	.693	.740	1.000	1.000	1.000	.508	1.000
70	.643	.721	.999	.939	1.000	.475	1.000
60	.610	.689	.990	.810	1.000	.438	1.000
50	.574	.659	.984	.600	1.000	.407	1.000
40	.541	.641	.980	.377	1.000	.388	1.000
30	.513	.633	.974	.182	.953	.372	.942
20	.476	.619	.955	0.000	.823	.335	.770
10	.440	.596	.932	0.000	.800	.268	.684

☆U.S. GOVERNMENT PRINTING OFFICE: 1977—771-057/20